

TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

365-460P

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/623018

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE

PRIORITY DATE CLAIMED

PCT/FI99/00153

February 26, 1999

February 27, 1998

TITLE OF INVENTION

PROCESS FOR PYROLYSING CARBONACEOUS FEEDSTOCKS

INVENTOR(S) FOR DO/EO/US

HILTUNEN, Jyrki; GUST, Steven; NIEMINEN, Jukka-Pekka

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
- a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
- b. ☒ has been transmitted by the International Bureau.
- c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(3)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(2)).
- a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
- b. ☐ have been transmitted by the International Bureau.
- c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
- d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.-1449 and International Search Report (PCT/ISA/210) w/ 11 references
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
- 1.) PCT Request (PCT/RO/101)
- 2.) PCT Demand (PCT/IPEA/401)
- 3.) International Preliminary Examination Report (PCT/IPEA/409)
- 4.) Two (2) sheets of Formal Drawings

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17. ☒ The following fees are submitted:**BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):**

Neither international preliminary examination fee (37 CFR 1.482)

nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO

and International Search Report not prepared by the EPO or JPO. \$970.00

International preliminary examination fee (37 CFR 1.482) not paid to

USPTO but International Search Report prepared by the EPO or JPO. \$840.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO

but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. \$690.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO

but all claims did not satisfy provisions of PCT Article 33(1)-(4). \$670.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO

and all claims satisfied provisions of PCT Article 33(1)-(4). \$96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☒ 30

months from the earliest claimed priority date (37 CFR 1.492(e)).

\$

130.00

CLAIMS NUMBER FILED NUMBER EXTRA RATE

Total Claims 24 - 20 = 4 X \$18.00 \$ 72.00

Independent Claims 2 - 3 = 0 X \$78.00 \$ 0

MULTIPLE DEPENDENT CLAIM(S) (if applicable) Yes + \$260.00 \$ 260.00

TOTAL OF ABOVE CALCULATIONS = \$ 1432.00

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity statement

must also be filed (Note 37 CFR 1.9, 1.27, 1.28). \$ 0

SUBTOTAL = \$ 1432.00Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30

months from the earliest claimed priority date (37 CFR 1.492(f)). \$ 0

TOTAL NATIONAL FEE = \$ 1432.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be

accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property + \$ 0

TOTAL FEES ENCLOSED = \$ 1432.00

Amount to be: \$

refunded

charged \$

a. ☒ A check in the amount of \$ 1432.00 to cover the above fees is enclosed.b. ☐ Please charge my Deposit Account. No. _____ in the amount of \$ _____ to cover the above fees.
A duplicate copy of this sheet is enclosed.c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any
overpayment to Deposit Account No. 02-2448.**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR
1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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REGISTRATION NUMBER

09/623018

533 Rec'd PCT/PTO 25 AUG 2000

PATENT
65-460P

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant: HILTUNEN, Jyrki et al.
Int'l. Appl. No.: PCT/FI99/00153
Appl. No.: New Group:
Filed: August 25, 2000 Examiner:
For: PROCESS FOR PYROYSING CARBONACEOUS
FEEDSTOCKS

PRELIMINARY AMENDMENT

BOX PATENT APPLICATION

Assistant Commissioner for Patents
Washington, DC 20231

August 25, 2000

Sir:

The following Preliminary Amendments and Remarks are respectfully submitted in connection with the above-identified application.

AMENDMENTS

IN THE SPECIFICATION:

Please amend the specification as follows:

Before line 1, insert --This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/FI99/00153 which has an International filing date of February 26, 1999, which designated the United States of America.--

IN THE CLAIMS:

Please amend the claims as follows:

Claim 4: Line 1, change "any of claims 1 to 3" to

--claim 1--

Claim 5: Line 1, change "any of claims 1 to 4" to
--claim 1--

Claim 6: Line 1, change "any of claims 1 to 5" to
--claim 1--

Claim 7: Line 1, change "any of claims 1 to 6" to
--claim 1--

Claim 8: Line 1, change "any of claims 1 to 7" to
--claim 1--

Claim 11: Line 1, change "any of claims 8 to 10" to
--claim 8--

Claim 12: Line 1, change "any of the preceding claims" to
--claim 8--

Claim 13: Line 1, change "any of the preceding claims" to
--claim 1--

Claim 18: Line 1, change "any of claims 15 to 17" to
--claim 15--

REMARKS

The specification has been amended to provide a cross-reference to the previously filed International Application. The claims have also been amended to delete improper multiple dependents and to place the application into better form for examination. Entry of the present amendment and favorable action on the above-identified application are respectfully requested.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional

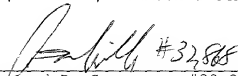
Docket No. 365-460P

fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17;
particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By

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Leonard R. Svensson, #30,330

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(Rev. 04/19/2000)

00623018-103400

PROCESS FOR PYROLYSING CARBONACEOUS FEEDSTOCKS**Background of the invention****Field of the Invention**

The present invention relates to thermal conversion processes, in particular to pyrolysis of carbonaceous feedstocks, such as biomass and organic wastes. According to the process, the carbonaceous material is fed into a reactor, wherein the feedstock is converted at moderate temperature in the presence of a heat transfer medium comprising particulate matter. The particulate matter is kept in fluidized state by a fluidizing gas. After pyrolysis, the particulate matter is separated from the hydrocarbon products, it is regenerated by combustion and recirculated to the reactor. The products of the pyrolysis comprise solids, liquids and/or gases which are recovered from the reactor. Optionally the products are subjected to further processing steps, for example by condensation of the vaporized hydrocarbons.

Description of Related Art

The continuing and increasing concern of society for environmental problems related to fossil fuel use and disposal of waste materials has led to increased research into and development and commercialisation of a wide variety of technologies which aim at enhancing the collection, processing and use of materials in an environmentally responsible manner.

At present the expanded use of organic based materials from solid waste streams and forestry residues or purpose grown crops is hindered by the relatively high costs in comparison to the existing infrastructure for employing fossil fuel systems. These high costs are due to both higher feedstock costs and higher conversion costs. The higher conversion costs are related to the well known problem of economy of scale, which is caused by the wide distribution of raw materials which leads to high costs for collection and transport. In terms of biomass conversion, the main goal is to increase the energy

concentration in the final product so as to minimize costs during use. Liquids are also preferred due to the ease of handling, shipping and storing as well as because of their favorable characteristics of use.

In general terms, pyrolysis is a thermal degradation process in which large molecules are broken or cracked into smaller molecules. It can be used to convert a variety of solid or liquid materials into a more readily useable form, and it has, in fact, been employed for the production of charcoal and high viscosity tars from biomass for centuries. The process can be described as a thermal cracking or a depolymerization process in the absence or near absence of oxygen. During the past 10-20 years, the technology has been modified to maximize liquid yields by increasing the heating rate to over 1000 °C/second, reducing the vapour residence time to under 15 seconds and improving the product recovery with a fast quench.

Depending on the feedstock, conventional pyrolysis equipment comprises a drier for the raw material, optionally a mechanical grinder for size reduction, a feed system, a reactor, cyclones for solids removal from the vapour stream, char combustor to provide heat for the reaction and pots for solids removal and recovery system. In addition, a char combustor for process heat is often included. The reactors operate at a slight overpressure.

The above-described process equipment is used for thermal conversion known as "flash" or "fast" pyrolysis. When applied to small biomass particles (<5 mm thick) and temperatures of 400 to 700 °C, liquid yields are as high as 65 to 75 wt-%. The other products of the process are char (10 to 15 wt-%) and non-condensable gases such as methane CH₄, carbon monoxide CO and carbon dioxide CO₂ (10 to 15 wt-%).

The ratio of solids to liquids to gases is determined by both the heating rate and maximum temperature and generally it depends on the specific feedstock. If liquid products are to be maximised it is generally known in the art that intermediate temperatures in the range of 400 to 600 °C and relatively short residence times from 0.5 to 5 seconds are most advantageous. These process conditions lead to high yields, on the order of 65 to 75 weight % of the feedstock.

In the art, heat for the endothermic pyrolysis reaction is produced in a separate boiler or regenerator by combusting the uncondensable gases, tar and combustible solids produced in the process. Heat is transferred from the boiler to the reactor by solid particles, e.g. sand. After the chemical reaction the solids may be covered by tar which is combusted in the boiler. Solids (combustible and sand) are generally removed from the gas stream by one or more cyclones, which are placed following the reactor.

Processes for pyrolysis of carbonaceous materials and equipments used in the processes are discussed in the following patents:

W.M. Hearon et. al, "Preparation of Unsaturated Hydrocarbons from Oxygen Containing Organic Materials" U.S Patent No. 3,148,227 Issued Sept. 8, 1964

C.K. Choi, "Process and Apparatus for Rapid Pyrolysis of Carbonaceous Materials" U.S. Patent No. 4,101,412 issued July 18, 1978

E.L. Capener, M. Low, "Method and Apparatus for converting Solid Organic Material to Fuel Oil and Gas" U.S. Patent No. 4,344,770 issued Aug. 17, 1982

E. Chornet, C. Roy, "Organic Products and Liquid fuels from Lignocellulosic Materials by Vacuum Pyrolysis" Canadian Patent No. 1,163,595 issued March 13, 1984

D.S. Scott "Pyrolysis Process for Biomass" Canadian Patent No. 1,241,541 issued June 6, 1988

D.A. Berg, " Method and Apparatus for Rapid Thermal Processing" Canada Patent No. 1,283,880 issued May 5, 1991

The present technology is hampered by some significant problems. Thus, in order to achieve high product quality it is necessary to remove as high percentage of solids from the gases as possible prior to condensation. Solids remaining in the liquid product significantly reduce product quality by clogging small passages in pumps, fuel lines and nozzles and are

also suspected to lead to increased polymerisation and subsequent increase in viscosity of the liquid fuel.

In the above-mentioned related art, the conventional cyclones and separate reactors and regenerators used have serious limitations restricting their utilization in biomass pyrolysis processes. Thus, the solids are subjected to high velocities in traditional cyclones, which leads to high attrition of both solids and construction materials. The required equipment is large and heavy. Outer surfaces are large, which causes large radiation losses. Vertical distances for solids transport are long, which requires expensive process control equipment.

Summary of the Invention

It is an object of the present invention to eliminate the problems of the prior art and to provide a novel process for pyrolysis of biomass, organic wastes and similar carbonaceous feedstocks.

It is another object of the present invention to provide a novel apparatus for pyrolysis of the afore-mentioned materials.

These and other objects, together with the advantages thereof over known processes, which shall become apparent from specification which follows, are accomplished by the invention as hereinafter described and claimed.

The present invention is based on using a reaction system utilising at least two internally concentrically arranged cylindrical chemical or physical conversion circulating fluidized bed reactors or thermal regenerators comprising multi-inlet cyclones which permits thermal conversion or pyrolyzation of carbonizable material into a number of liquid, solid and gaseous products.

In particular, the process according to the present invention comprises pyrolysing biomass or organic wastes at temperatures in excess of 400 °C in an apparatus including a reactor

with a riser having an axially annular cross section and being equipped with a multi-inlet cyclone for the separation of particulate matter, and a regenerator with a riser having an axially annular cross section and being concentrically fitted in respect of the reactor used, said regenerator also being equipped with a multi-inlet cyclone for separation of regenerated particulate matter. According to the invention, the dipleg of the regenerator communicates with the riser of the reaction unit and with the drying unit.

More specifically, the process according to the present invention is mainly characterized by what is stated in the characterizing part of claim 1.

The apparatus according to the invention is characterized by what is stated in the characterizing part of claim 15.

The present invention achieves considerable advantages. Thus, the traditional problem of high solids content in liquid products has been minimised and it is possible to produce pyrolysis oil, the quality of which is higher than that of oil produced with the processes of the prior art. The incorporation of multi-inlet cyclones into the reactor configuration reduces gas velocities, reduces the physical size of the cyclone and shortens the residence time of gases in the cyclone. This directly leads to a reduction in the outer wall area of the hot reactors, which as a consequence leads to less material required and thus a less expensive reactor. Further, lower gas velocities cut down attrition of construction materials.

Next, the invention will be described in more detail by making reference to the appended drawings.

Brief Description of the Drawings

Fig. 1 shows a sectional side view of a preferred embodiment of the pyrolysis apparatus according to the present invention.

Fig. 2 shows a partial sectional view of a simplified structure of another preferred embodiment of the present invention.



Detailed Description of the Invention

Within the scope of the present invention, the terms "thermal conversion" and "pyrolysis" will be used interchangeably to denote a thermal process in which organic material selected from biomass and organic wastes is treated at moderate or high temperatures to produce useful solid, liquid and/or gaseous products.

In the context of thermal conversion, "moderate temperatures" are temperatures in the range of about 400 to about 800 °C, typically up to 600 °C, whereas "high temperatures" are temperatures in excess of 800 °C. The expression "an elevated temperature" covers both temperature ranges.

The terms "regenerator", "solids reheater" and "char combustor" are synonymously used for designating a reaction zone in which heat transfer particles are reheated for burning off any pyrolysis product accumulated on the surface of the particles and for increasing the heat content of the particulate matter.

The pyrolysis system of the present invention performs thermal conversion of carbonizable input material into char, condensable gases and non-condensable gases. The process comprises the steps of drying and grinding the feedstock, thermally converting or pyrolysing the feedstock in the presence of a heat transfer medium, separating products and heat transfer medium, regenerating heat transfer medium and recovering the products of the thermal conversion.

The apparatus comprises typically a feedstock feeder, a flash pyrolysis reactor, fluidizing gas input, multi inlet cyclone(s), sand reheater or regenerator, condensers and liquid storage for the liquids produced by pyrolysis.

Depending on the type and form of material, the input material is first dried to a moisture content of 5 to 25 % but preferably 7 to 12 %, and optionally converted to a finely divided raw material of appropriate size.

A heat transfer medium comprising solids, for example sand but it may also include catalysts, is fluidized by an essentially oxygen-free gas, such as flue gas, in a reactor space, where input material is fed. The heat transfer medium forms a fluidized bed within the reactor space. The fluidized bed can be formed in a reactor of conventional type, such as in a fluidized bed reactor, or the reactor can be a circulating fluidized bed reactor (CFBR). In the latter type the fluidizing velocities are so high that the bed surface is no longer sharply defined but replaced by a zone, wherein the solids content slowly decreases with the height. If particles are fine, this leads to fast fluidization where the solids entrainment occurs at such high rates that, in general, fast fluidized beds can only be maintained by recirculation of the entrained solids via cyclones.

According to the invention, the thermal conversion of the feedstock is performed in a circulating fluidized-bed reactor in which the reaction space, i.e., the fluidization space of the reactor comprises an intershell space of axially annular cross section remaining between two concentrically located cylinders or cones, in which space the feed is first suspended or vaporized into the fluidized bed and subsequently converted into reaction products at an elevated temperature.

The temperature, velocity and mass of the heated bed material are adjusted such that the resulting pyrolysis process maximizes the yield of the desired product. Input material is quickly heated by hot heat transfer media with residence times in the range of 0.01 to 10 seconds, preferably 0.1 to 2 seconds to a final temperature of 450 to 600 °C and is thus thermally converted or pyrolyzed into useable gases and solids.

Solids and bed material are then subsequently removed to percentage of more than 99.5% from the reaction gas by means of a multi-inlet (in the following also "multiport") cyclone, which is located directly above the axially annular reactor riser space. This arrangement makes it possible to shorten the residence time of the reaction, because a multiport cyclone offers faster and more efficient separation of particulate matter from the reaction gas flow over a single-port cyclone. From the cyclone, the particulate matter can be recirculated to a regenerator via a solids return channel, or the downward dipleg, which is formed by an intershell space of axially annular cross section remaining between

two concentrically located cylinders or cones.

According to a preferred embodiment, the regenerator comprises a riser and dipleg of a construction similar to that of the above-described reactor and fitted concentrically around the reactor to provide a compact construction.

In the regenerator, the solids are then fluidized by air or another oxygen-containing gas; the char is combusted while it flows vertically with the air in the surrounding outer regenerator reactor or char combustor. Combustion raises the temperature of the bed material to the operating conditions needed in the reactor.

As mentioned above, the risers and diplegs of both the reactor and the regenerator have axially annular cross sections and are coaxially placed. According to further preferred embodiment of the invention, the drier used for pretreating the feedstock comprises a third riser with a corresponding dipleg concentrically fitted around the combined reactor and regenerator. It is possible to provide channels for internal recirculation of material within at least one of the drier, the reactor and the solids reheater as well as for providing communication between the dipleg of the drier and the riser of the solids reheater and between the dipleg of the regenerator and the riser of the reactor. The dipleg of the reactor can be combined with the risers of both the drier and the regenerator.

The pyrolysis gases produced can be channelled to a series of condensers where they are condensed with the noncondensable gases continuing returning to either the drier or the char combustor for energy recovery.

A wide variety of feedstocks can be used as input materials for the reactor system. The common denominator for the feedstock materials is that it is carbon containing or carbonaceous. These can be broken down into two main categories: biomass and wastes:

The biomass feedstock is preferably selected from forestry residues and thinnings; agricultural residues, such as straw, olive thinnings; energy crops, such as willow, energy hay, Miscanthous; and peat.

The wastes are preferably organic, solid or liquid, and they are selected from refuse derived fuel (RDF); wastes from sawmills, plywood, furniture and other mechanical forestry wastes; plastic wastes; and waste slurries (including industrial and municipal wastes).

5 An apparatus according to the novel construction comprises an inner reactor of axially annular riser cross section and an outer solids reheater in which contaminated and cooled solid particles can be reheated and returned back to the process. In the following description, the circulating solids are denoted by abbreviation "CS".

10 Turning now to Figure 1, it can be noted that the apparatus according to the first embodiment of the present invention comprises two concentrically adapted cylindrical CS reactors, separated by an intermediate shell 22 from each other, of which the inner will later be called the "reactor" or "reaction unit" and the outer the "regenerator" or "regeneration unit".

15 The reactor unit is made from two or, as shown in the figure, preferably three concentrically mounted, essentially cylindrical tubes 1, 2 and 3, whose intertube spaces form spaces 20, 19 and 13 of axially annular cross section. The tubes may be made from steel or an equivalent alloy. Among these, the desired reaction is carried out in the space 20
20 13. The tubes are mounted with their longitudinal axes aligned concentrically vertical. Above the axially annular riser space 13, as a continuation of tubes 2 and 3, is mounted a multiport cyclone 14, 17 having louvered vanes 14 fixed to its outer wall. The cyclone is provided with a center tube 21 for removal of the product gas, while transfer channels 19 and 20 are provided in the inner space of the inner steel tube 3 for removal of the solids
25 separated from the gaseous phase in the cyclone.

Outside the reactor outer shell 3, the regenerator unit comprises three concentrically mounted, essentially cylindrical tubes 4, 5 and 6, whose intertube spaces form spaces 29, 28 and 24 of axially annular cross section. Among these, solids reheating is carried out
30 in the space 24. From inside, the pressure shell 6 is lined with an insulating material layer 7 in order to maintain the shell temperature at a reasonable level for shell strength. In a similar fashion as in the reactor, above the axially annular space 24 is mounted a

multiport cyclone 25, 26, whose vanes are attached either to the cylindrical tube 5 or the pressure shell 6. The cyclone is provided with a center tube 30 for the removal of the stack gas formed in the regenerator, while transfer channels 28 and 29 are provided by means of steel tubes 5 and 6 for removal of the catalytic solids separated from the gas phase in the cyclone.

The fluidization gas flow of the reactor is denoted in the diagram by reference numeral 8. The gas flow 8 enters the reaction space through a fluidization bottom 12 above which it is first mixed with the catalyst entering via a return channel 20 via a valve 31, and then higher in the reactor riser, with the feed flow 10 injected via nozzles 17 or fed using a screw feeder via channels 16 into the reaction space. The mixed gas flows 8 and 10 move in a gaseous phase along the axially annular riser 13 simultaneously carrying the entrained solids therewith into the vanes 14 of the reactor cyclone. The catalyst releases heat into the feed vaporization and the reaction occurring in the riser 13, whereby its temperature falls. From the vanes 14, the gas and entrained solids enter tangentially the interior of the inner reactor cyclone chamber 17, where the solids are separated by impinging on cyclone inner wall 18 and falling into the solids transfer channels 19 and 20. When required, a portion of the solids can be returned as an overflow back to the reactor bottom section via an axially annular, internal recirculation channel 19. While the channel 19 is not essential to the function of the apparatus, it may in some cases be advantageous to the reaction. In the channel 20, the solids dribble downward in a dense phase, whereby the mixing of the gas flows between the reactor and the regenerator via the solids transfer channel 20 will be inhibited. The gas flow 11 entering the reactor cyclone exits the reactor via the center tube 21 of the inner cyclone. The solids flow from the reactor into the regenerator is controlled by means of a valve 31 equipped with a cylindrical control element, which is arranged mechanically movable by means of bars 32.

The regenerator is adapted about the reactor so that these units are separated from each other by a transfer channel 29 filled with solids in a dense phase. In a similar fashion with the reactor, the regenerator is located in the intershell riser space remaining between two cylindrical envelope surfaces formed by the apparatus shell and the reactor tube

mounted inside the shell. Between said reactor tube and said outer cylindrical shell structure of the reactor is further mounted a cylindrical wall to provide said solids transfer channel 29. An oxygen-containing gas flow (e.g. air) 9 enters the solids reheater via a fluidizing distributor bottom 23 and rises in the axially annular riser channel 24 simultaneously therewith carrying the solids into the vanes 25 of the regenerator cyclone. In the reheater, coke possibly accumulated on the surface of the solids and organic compounds penetrated in the pores thereof are oxidized, that is, burned in the riser channel 24, whereby the solids temperature is elevated. The regenerator cyclone chamber 26 is located above the reactor proper. In the cyclone chamber 26, the solids are separated by impinging on the cyclone wall 27 and subsequently fall into channels 28 and 29. The return channel 29 passes the catalytic solids back to the reactor. That excess portion of the solids which fails to enter the return channel will fall back to the regenerator bottom section as an overflow via the channel 28. The particulate matter is advantageously kept in a fluidized state during its passage in the internal return channel, whereby a control valve is redundant. The stack gas 12 of the regenerator is removed via the central tube 30 of the regenerator cyclone. The solids dribbling slowly downward in the return channel 29 in a dense phase prevent communication between the gas spaces of the reactor and the regenerator. The solids flow rate from the regenerator to the reactor is controlled by moving the cylindrical control element of a valve 33 mechanically via bars 34 connected thereto.

For wet materials such as slurries, saw dust etc., comprising finely-divided solid matter, the embodiment shown in Fig. 2 can be used. It comprises a pyrolysis apparatus consisting of a reactor 41 and a dipleg 42. The reactor includes a channel 52 for internal recirculation of unreacted biomass and solids. Said channel is preferably fitted between the reactor and the dipleg. The axial cross-sections of the riser, the dipleg and the recirculation channel are annular. A regenerator or solids reheater 43 having an axially annular cross-section is concentrically fitted within the reaction unit 41, 42, 52. The regenerator includes a channel 44 for internal recirculation of treated matter and a central cylindrical dipleg 45 communicating with the riser of the reactor 41. A drier or drying unit 46-48 is concentrically fitted about the reaction unit 41, 42, 52. The construction of the drier is similar to that of the reactor and the regenerator comprising a channel for internal

recirculation 47 having an axially annular cross-section and a dipleg 48 of similar cross-section.

Each of the risers having axially annular cross-sections are provided with multi-inlet cyclones 49 - 51 at the top (as a continuation of the tubes defining the risers), for separating solids and gas.

The connections and communicating channels between the drying unit, the reactor and the reheater are shown in Figure 2. As readily seen, a channel 53 formed in the lower part of the apparatus will provide contact between the dipleg 45 of the reheater and the risers 41, 46 of the reactor and the drier. The riser of the reactor 41 is also connected to the dipleg of the drier 48. The flux of material between the diplegs of the various sections within said communicating channels are adjusted by means of control valves 54 - 57.

For fluidizing the solids in the reactor 41, flue gases obtained, for example, from the reheater can be used. Flue gases are also preferably used for drying of the feedstock. Air and possibly uncondensed pyrogases (from the reactor) can be fed into the reheater 43 for burning off pyrolysis products on the surface of the solids.

The gaseous products obtained from the reactor can be condensed in a condenser cascade (not shown) to produce liquid pyrolysis products, useful as, e.g., fuels.

Example

Forestry residues are collected and shipped to the pyrolysis process plant. For the apparatus shown in Figure 1, the feedstock is dried in a separate drier (not shown) to an appropriate moisture content, normally less than 15 weight percent and ground, chopped or hammered to an appropriate thickness and length before being fed into the reactor system by a screw feeder.

In the embodiment shown in Figure 2, the wet feedstock is fed to the drying section, in which it is dried to desired moisture content, at least a part of the material being

recirculated through channel 47. Humid flue gas is released from the drier and a part of the dried material is conducted via the dipleg to the reactor wherein it is mixed with the particulate heat transfer matter (e.g. sand).

- 5 Either flue gases from the sand reheater / regenerator 43 or non-condensable gases from the liquid collection section are compressed and fed into the reactor 41 for bed fluidization. The input material is fed into the reactor assembly at the bottom of the reactor at the point where the heated bed material is returned to the reactor.
- 10 In either alternative the input particles are then rapidly heated in 0.5 to 5 seconds to the operational temperature of 450 to 600 °C where they undergo the thermal conversion or pyrolysis reaction forming a mixture of condensable vapors, solids and noncondensable gases. The solid char and bed material are removed from the gas stream by a multi-inlet port cyclone and the pyrolysis vapors are directed into a series of condensers where the
- 15 temperature is lowered from a temperature in the range of 450 to 600 °C to a final temperature of 40 to 60 °C. The vapors are condensed and mixed to give a final yield of liquid from 50 to 75 weight percent. Non-condensable gases which are comprised mostly of carbondioxide, carbon monoxide and methane are utilized in either the drier as a source of heat or the regenerator as a source of heat or as the fluidizing gas.
- 20 In the regenerator section 43, the bed material is heated by oxidising combustible solid char removed from the gas stream by the multi inlet port cyclone and also if desired by noncondensable gases from condensers. As fluidizing gas air (ambient air or hot humid air from drier) is used. Flue gases from regenerator is used for pyrolysis reactor fluidizing gas
- 25 and/or for drying of feedstock together with solid char.

Claims:

1. A process for thermal conversion of carbonaceous feedstocks selected from biomass and organic wastes, in which method

- the feedstock is fed into a fluidized-bed reactor (1-3; 41, 42, 52), wherein the feed is converted at an elevated temperature under the influence of particulate matter kept in a fluidized state by a fluidizing gas,
- the particulate matter is transferred from the reactor to a regenerator (24, 28, 29; 43-45) for regeneration and then recirculated to the reactor after the regeneration, and
- the converted hydrocarbon products are recovered from the reactor,

characterized by using

- a reactor (1-3), which comprises a riser (13; 41) having an axially annular cross section and being equipped with a multi-inlet cyclone (14, 17; 50) for the separation of particulate matter, and
- a regenerator (24, 28, 29; 43-45), which comprises a riser (24) having an axially annular cross section and being concentrically fitted in respect of the reactor used, said regenerator being equipped with a multi-inlet cyclone (25, 26; 51) for separation of regenerated particulate matter.

2. The process according to claim 1, wherein the reactor comprises an intershell riser space (13; 41) formed between two concentrically located cylindrical and/or conical envelope surfaces.

3. The process according to claim 1 or 2, wherein the vapour residence time of said process is 0.1 - 5 s.

4. The process according to any of claims 1 to 3, comprising using a multiport cyclone (17) equipped with louvered vanes (14).

5. The process according to any of claims 1 to 4, wherein the reactor (41, 42, 52) is a circulating fluidized-bed reactor optionally having a channel (52) for internal circulation.

6. The process according to any of claims 1 to 5, wherein the regenerator (43-45) is provided with a channel (44) for internal recirculation.

7. The process according to any of claims 1 to 6, wherein the regenerator is provided with a dipleg (29; 45), which communicates with the riser of the reactor.

8. The process according to any of claims 1 to 7, wherein the feedstock is dried in a drier (46-48) comprising a riser (46) having an axially annular cross section and being equipped with a multi-inlet cyclone (49) for the separation of dried matter from vaporized gases.

9. The process according to claim 8, wherein the drier is provided with a dipleg (48), which communicates with the riser (41) of the regenerator.

10. The process according to claim 8 or 9, wherein the drier (46-48) is provided with a channel (47) for internal circulation.

11. The process according to any of claims 8 to 10, wherein the dipleg (45) of the regenerator communicates with the riser of the drier (46).

12. The process according to any of the preceding claims, wherein the feedstock is thermally converted at a temperature of 400 - 1000 °C.

13. The process according to any of the preceding claims, wherein the feedstock is selected from forestry residues and thinnings, agricultural residues, energy crops, peat, refuse derived fuel, wastes from sawmills, plywood, furniture and other mechanical forestry wastes, plastic wastes and waste slurries.

14. The process according to claim 13, wherein the feedstock is selected from straw, olive thinnings, willow, energy hay and Miscanthous.

15. An apparatus for thermally converting carbonaceous feedstocks, said apparatus

comprising

- a drying unit (46-48) for drying the feedstock,
- a reaction unit (41, 42, 52) in which the feedstock is contacted with hot, fluidized-state particulate matter, and
- a regenerator unit (43-45) for regeneration of the particulate matter contaminated in the first unit process,

characterized in that

- the reaction unit comprises a riser (41) with an axially annular cross section and having a multi-inlet cyclone (50) for separating solids from gas, and
- the regenerator unit comprises a circulating fluidized-bed reactor (43, 44) and a dipleg (45) fitted about the reaction unit (41, 42, 52) in a symmetrically concentric fashion, said riser (43) having an axially annular cross section and being equipped with a multi-inlet cyclone (51) for separation of solids from gas, said dipleg (45) of the regenerator unit communicating with the risers (41, 46) of the reaction unit and with the drying unit.

16. The apparatus according to claim 15, wherein the regenerator unit (43-45) comprises a channel (44) for internal recirculation of solid matter within the regenerator unit.

17. The apparatus according to claim 15 or 16, wherein the reaction unit (41, 42, 52) comprises a channel (52) for internal recirculation of solid matter within the reactor.

18. The apparatus according to any of claims 15 to 17, wherein the drying unit (46-48) comprises a riser (46) fitted about the reaction unit in a symmetrically concentric fashion, said riser having an axially annular cross section.

19. The apparatus according to claim 18, wherein the drying unit (46-48) comprises a dipleg having an axially annular cross section and communicating with the riser (41) of the reaction unit.

20. The apparatus according to claim 18 or 19, wherein the riser (46) of the drying unit is equipped with a gas and solids separating means formed by a multi-inlet cyclone (49).

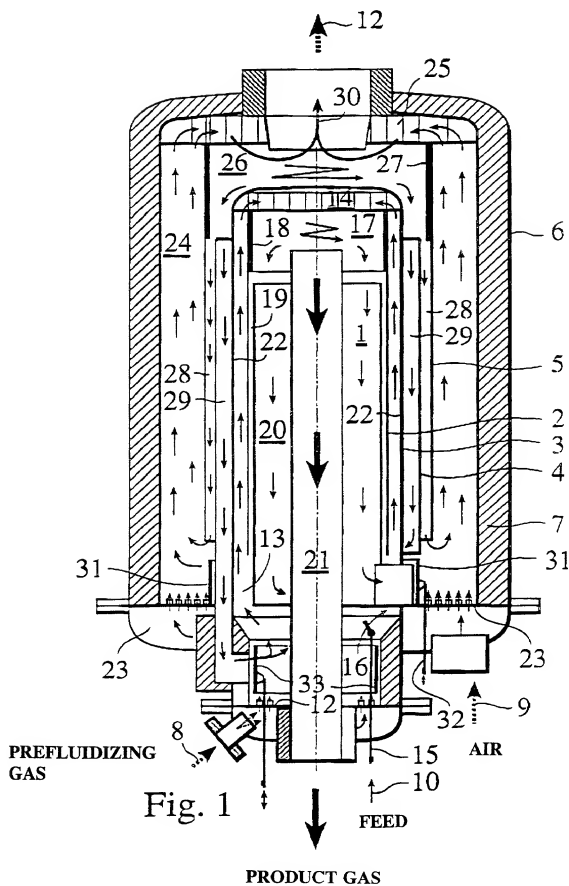
(57) Abstract

The present invention concerns a process and an apparatus for thermal conversion of biomass and organic wastes. According to the invention the feedstock is fed into a fluidized-bed reactor (1-3), wherein the feed is converted at an elevated temperature under the influence of particulate matter kept in a fluidized state by a fluidizing gas, the particulate matter is transferred from the reactor to a regenerator (24, 28, 29) for regeneration and then recirculated to the reactor after the regeneration, and the converted hydrocarbon products are recovered from the reactor. Both the reactor (1-3) and the regenerator comprise risers (13, 24) having an axially annular cross section and being equipped with a multi-inlet cyclones (14, 17, 25, 26) for the separation of particulate matter. By means of the invention it is possible to produce pyrolysis oil, the quality of which is higher than that of oil produced with the processes of the prior art. The incorporation of multi-inlet cyclones into the reactor configuration reduces gas velocities, reduces the physical size of the cyclone and shortens the residence time of gases in the cyclone.

(Figure 1)

1/2

REGENERATOR
STACK GAS



PRODUCT GAS

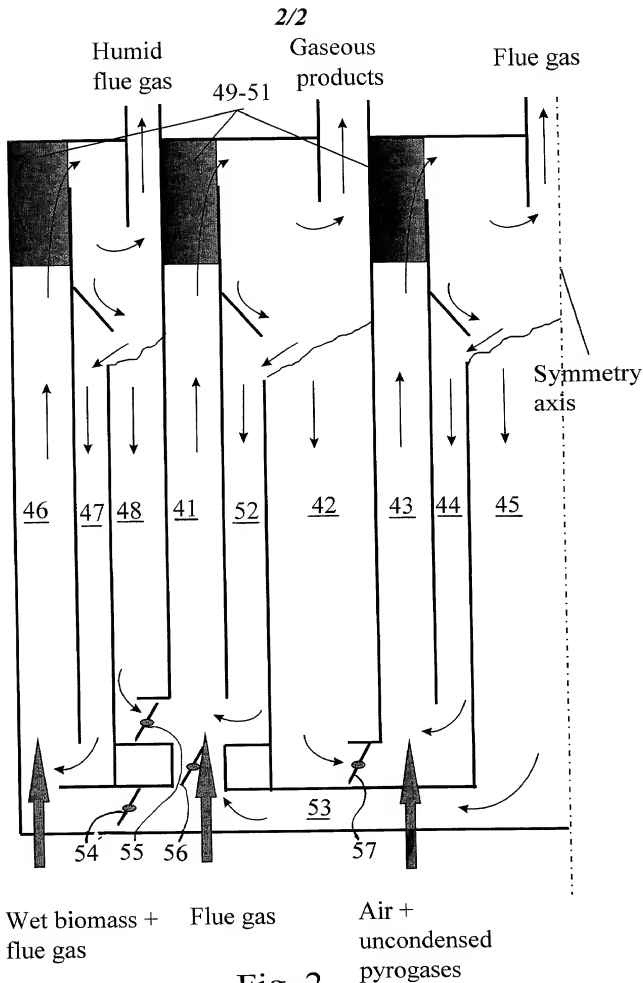


Fig. 2

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As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated next to my name; that I verily believe that I am the original, first and sole inventor (if only one inventor is named below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:
Process for pyrolysing carbonaceous feedstocks

Fill in Appropriate
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Specification
Attached:



the specification of which is attached hereto. If not attached hereto,
the specification was filed on August 25, 2000 as
United States Application Number 09/623,018; and /or
the specification was filed on February 26, 1999 as PCT
International Application Number PCT/FI99/00153; and was
amended under PCT Article 19 on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (six months for designs) prior to this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows.

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Information:
(if appropriate)



Prior Foreign Application(s)

<u>980456</u> (Number)	<u>Finland</u> (Country)	<u>February 27, 1998</u> (Month/Day/Year Filed)
_____ (Number)	_____ (Country)	_____ (Month/Day/Year Filed)
_____ (Number)	_____ (Country)	_____ (Month/Day/Year Filed)
_____ (Number)	_____ (Country)	_____ (Month/Day/Year Filed)
_____ (Number)	_____ (Country)	_____ (Month/Day/Year Filed)

Priority Claimed

<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
<input type="checkbox"/> Yes	<input type="checkbox"/> No
<input type="checkbox"/> Yes	<input type="checkbox"/> No
<input type="checkbox"/> Yes	<input type="checkbox"/> No
<input type="checkbox"/> Yes	<input type="checkbox"/> No
<input type="checkbox"/> Yes	<input type="checkbox"/> No

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_____	_____
(Application Number)	(Filing Date)
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I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

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(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)
_____	_____	_____
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I hereby appoint the following attorneys to prosecute this application and/or an international application based on this application and to transact all business in the Patent and Trademark Office connected therewith and in connection with the resulting patent based on instructions received from the entity who first sent the application papers to the attorneys identified below, unless the inventor(s) or assignee provides said attorneys with a written notice to the contrary:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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 Document is Signed

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